The Global Warming Debate

AARST, Nov. 20, 1998, New York

Statements by Dr. James Hansen

[Note: Section numbering corresponds to slides which follow the text.]

1. Debate topic

Thanks, Dr. Mitchell. I'm going to use slides and some scientific charts — I hope that this opening statement that I have put together will serve as a good summary of the debate topic.

The issue we were asked to debate: Is there sufficient scientific evidence that proves we should substantially limit greenhouse gas emissions because of climate change?

I will take the affirmative side. I will interpret this question as a scientific one. I do not want to get involved in a political discussion.

2. My opinion

I will present evidence that climate is changing, global warming has started, and human-made greenhouse gases are at least partly responsible.

Also, global warming tends to increase climate extremes — the frequency of droughts and fires, at one extreme, but also heavy rain and floods.

I will argue that detrimental effects of large climate change probably exceed beneficial ones.

So it makes sense to begin to take common sense steps that help limit future climate change.

3. Greenhouse gases

During the past few decades measurements of atmospheric composition — including bubbles of old air that were trapped in the ice sheets of Greenland and Antarctica as snowfall piled up year after year and was compressed into ice — these measurements show that certain trace gases have been increasing in the air during the industrial period, especially CO_2 from burning of fossil fuels, coal, oil and gas.

4. Greenhouse effect cartoon

These gases are transparent to sunlight coming through the atmosphere, but they absorb heat radiation from the Earth's surface and radiate some of that heat back down, causing a heating of the surface. I became interested in this problem in the 1970s when several of us at our institute calculated the heating caused by all of these gases that have accumulated in the air since the industrial revolution began. We found that the total heating was close to two Watts per square meter.

One Watt is the amount of energy given off by a miniature Christmas tree bulb. So its like having two of these bulbs over every square meter of the Earth, burning day and night and slowly getting brighter. Is that important? It's not obvious. The Earth absorbs 240 Watts per square meter of sunlight averaged over the Earth, so it's as if the brightness of the sun increased by 1%. The natural variations in the brightness of the sun measured during the past few decades are only a few tenths of a Watt per square meter. On this basis it appears that a human-made climate forcing, the greenhouse effect, is already competitive with natural climate forcings.

5. Charney report

Possible greenhouse warming was of sufficient concern that in 1979 the science advisor to the President requested the National Academy of Sciences to study the matter. It resulted in the famous Charney report from a committee of many of the most reputable scientists in the country in relevant fields.

The Charney review focused on the question: how much would the world warm, on average, if the amount of CO_2 in the air doubled, which could happen next century if growth rates continue to increase. It's a hard problem. The world will take a long time to respond to such a forcing, because the ocean has great thermal inertia. Also as the world warms other things will change, the amount of water vapor in the air, clouds, the snow cover on the ground.

Charney concluded that there are at least two feedbacks that affect global climate sensitivity. One is water vapor: as the atmosphere becomes warmer it can hold more water vapor, and because water vapor is a greenhouse gas, it increases the warming.

The other feedback is from snow and ice. Models, theory and observations all indicate that as the world become warmer, the area covered by snow and ice is smaller. This is a positive feedback because high albedo snow and ice surfaces are replaced by darker ocean or land, which absorbs more sunlight causing additional warming.

There are other feedbacks. Cloud can cause both negative and positive feedbacks. We don't understand all the feedbacks. That's why Charney

estimated such a broad range for climate sensitivity, anywhere between 1.5 and 4.5°C.

Charney realized the staggering implications of a climate sensitivity of 3C. After all, the world on average was only about 5C colder during the last major ice age, and not more than about 5C warmer than now during the age of the dinosaurs. In a masterful summary statement Charney wrote "we have tried but have been unable to find any overlooked or underestimated physical effects that could reduce the currently estimated global warming due to doubling atmospheric CO_2 to negligible proportions…".

It's easy to dream up negative feedbacks that somehow will make climate sensitivity small. There are lots of Rube Goldberg ideas. Fortunately, the history of the Earth provides an invaluable check on climate sensitivity.

6. Paleoclimate map

Based on geological evidence we know the conditions on the Earth's surface during the last ice age, about 20,000 years ago. For example, an ice sheet as much as two miles thick covered Canada, parts of the U.S., Europe and Asia. Vegetation distributions were different, and even the coast lines because sea level was 400 feet lower.

We know the composition of the ice age air from bubbles of air trapped in the ice sheets at that time. There was less CO_2, less methane and less nitrous oxide, and there was more dust in the air during the ice age.

7. Ice age bar graph

Averaged over several thousand years the Earth must be in radiation balance with space (emitting the same amount of energy that it absorbs from the sun) within a fraction of 1 W/m^2, as we can easily see by calculating the energy it takes to melt the ice sheets or raise ocean temperature by a plausible amount. So the world provides an empirical measure of climate sensitivity, which is just the ratio of the observed global temperature change, about 5°C, divided by the forcing that maintained that temperature change, which was somewhere between 6 and 9 W/m^2.

The result is 3/4°C for 1 Watt forcing, which is about 3°C for a doubled CO_2 forcing of 4 W/m^2, in good agreement with Charney's estimate. The great thing about this empirical measure is that it includes all the feedbacks that exist in the real world — not only ones we know about, but any Rube Goldberg feedback that exists, if it really occurs, it's in there. Changes in clouds, water vapor, ocean heat transport; they are all in there.

Global warming skeptics pretend that warming is just a product of climate models, but in fact it arises from the most basic theory as well as models, and, what's more important, it is well tested by empirical evidence, including other planets and the Earth's history.

8. CO_2 warming vs noise level (Fig. 7 of 1981 Science paper)

Nevertheless, it's important to assess how well climate models can simulate the climate. The best way to do that is to compare model predictions with the real world.

Do the models exaggerate global warming? The first model predictions for greenhouse gas scenarios were our calculations a couple decades ago with a simple climate model with sensitivity 2.8°C for doubled CO_2. We published a paper in *Science* that was reported by Walter Sullivan in a front page article of the *New York Times*. The model prediction, shown here, was a warming of a quarter of a degree Celsius from the late 1970s to now. We argued that would be about enough to bring the warming out of the noise level, the unforced chaotic fluctuations of climate, in the 1990s. This is the five-year running mean temperature, and the noise level, the shaded area, is based on the variability of observed five year mean temperatures.

9. Global mean temperature: annual and 5-year mean

What has the real world done? The five-year running mean temperature, the red curve, has indeed warmed up about a quarter of a degree. In the last few years several papers, and the report of the Intergovernmental Panel on Climate Change, have concluded that the observed warming is now probably too large to be natural variability. So the most basic prediction of our paper proved to be correct.

And this warming is real. Contrary to claims of the skeptics, it is not urban warming. The warming is hardly changed if only rural measurements are used. The magnitude of global warming is confirmed by borehole data from many locations around the world, where the vertical gradient of subsurface temperature yields an average warming of 2 to 1°C in the past century. Also glaciers have receded almost world-wide in the past century, and the magnitude of their recession has been used to infer a global warming of about 0.8°C in the past century.

10. Global map of 1951-95 temperature change

This is the global distribution of temperature change in the past 5 decades. The geographical distribution of the warming, with the largest change in remote Siberia, Canada and mid-ocean areas debunks any attempt to ascribe the warming to urban effects. Global warming is real.

11. 1988 global temperature prediction

The first model predictions with a 3-D climate model and time-dependent climate forcings were those we published in 1988, which were the

basis for my testimony to congress that year. The climate forcings in the model were greenhouse gases and stratospheric aerosols. There were three scenarios for greenhouse gases, A, B and C, with B and C being nearly the same until 2000, when greenhouse gases stopped increasing in scenario C. Real world forcings have followed the BC greenhouse gas scenario almost exactly. The model scenarios had one large volcano in the 1990s, in 1995, and one actually occurred, but in 1991. If we shift the date of the volcano, the model and data fit remarkably well.

This record, by itself, is too short to serve as a conclusive test. But again there is no hint that the model exaggerates global warming B in fact, the real world has warmed slightly more than in the model using actual greenhouse gas changes.

12. Congressional testimony

In 1988 and 1989, in testifying to the United States Senate, I asserted that (1) the world was in a period of real long-term global warming, (2) that the warming was probably due, at least in part, to human-made greenhouse gases, and (3) that in our climate simulations global warming was accompanied by increasing climatic extremes. An increase in both droughts and forest fires, on the one hand, and heavy rain and floods, on the other, makes sense. Although climate fluctuates chaotically at any given place, at times when it is dry the added greenhouse heating intensifies the dryness. But over the ocean, at other places where it is wet, and on the global average, increased surface heating increases evaporation and thus rainfall, which falls increasingly in more intense penetrating convection, causing enhanced flooding.

13. Colored dice

I soon realized that there was a possible misinterpretation of this testimony by the public, perhaps inferring that every season would be unusually warm. So I made a set of colored dice to illustrate that global warming is smaller than unforced chaotic fluctuations of climate, but by the 1990s there could begin to be a significant loading of the climate dice. This analogy to dice was based on our 1988 paper.

14. Frequency of hot summers

… in which we calculated that the frequency of unusually warm seasons, in locations such as Omaha and Washington, would increase from the 33% for the 1950-1980 period to 50-80% in the 1990s, depending on the greenhouse gas scenario. In the BC scenarios, which observed greenhouse gases have actually followed, the increase was from 33% to 50-60%.

15. Frequency of warm seasons

This is real world data. The frequency of warm seasons, although it's highly variable from year to year, has increased to 50-60% at middle latitudes, where we made predictions, as shown on the left, as well as on the global average, which is on the right.

This frequency of unusually warm seasons begins to touch a key point — when will climate change be obvious to people — to most people? I'm not certain whether people can notice a change in probabilities from 33 to 50-60%, but I think that we are at least getting very close to a level of change that will be noticeable to the perceptive person. Should we expect these probabilities to continue to increase?

16. Growth rate of greenhouse gas forcing (Fig. 5 of Indus. Era)

Yes, for two reasons. First, the warming due to the gases we have already added to the atmosphere is only partly realized, because of the long response time of the climate system. Second, greenhouse gases are still increasing rapidly.

This last slide shows that climate forcing by greenhouse gases is continuing to grow, but not as fast as 10 years ago, because CFCs are being phased out, methane increases have slowed, and the CO_2 growth rate has flattened out.

This is an encouraging result, because it shows that greenhouse gas growth rates do not have to get larger and larger — they have in fact declined during a period of economic prosperity. But further decline is needed to prevent the equivalent of doubled CO_2 next century.

17. Summary Statement

There is abundant empirical evidence, especially from paleoclimate records, that climate is sensitive to forcings. And there is no doubt that greenhouse gases are increasing rapidly giving rise to a strong climate forcing. Global warming is observed, it seems to be rising above the noise level of natural climate variability, and it is consistent in magnitude with the warming expected from the climate forcing.

There are large uncertainties about future climate change, especially because of uncertainties about how different climate forcings will continue to change. But as long as we let greenhouse gases continue to increase rapidly, we almost surely are headed to a much warmer planet.

What the impact of that will be is uncertain, but we are adapted to the current climate — e.g., if sea level goes up one meter, that will be very detrimental to much of our coast line, not to mention essentially wiping out the Maldives, the Marshall Islands, the Nile delta, Bangladesh.

So it seems to me that, given the potential dangers we can foresee, a common sense strategy would be to take steps that slow down the

planetary experiment, and then adjust that strategy as we see how climate continues to unfold.

There are many opportunities to slow down this experiment, things we can do that would make good common sense in any case. For example steps to improve energy efficiency would reduce the rate of growth of greenhouse gases and make good economic sense. And we should invest in clean renewable energy technologies so that, if the evidence continues to mount, we will be in a position to move more expeditiously on our long-term choices of energy sources.

Questions from Affirmative Side

Pat has raised many issues, a few of which are valid, many of which are misleading or half-truths, and some of which are just plain wrong. How can we avoid getting bogged down in a morass of technical issues and contradictory statements? I will try to ask a few questions that relate to the bottom line. I hope that these questions are fair. I know that neither of us has any expertise in energy or economics. But perhaps when the audience participates later we can come back to these topics.

Q1. Just after I was asked to participate in this discussion I saw a newspaper article that seemed relevant, about British Petroleum.

BP Statement *[slide 18]*

…announced a "firm target" of cutting emissions by 10% of 1990 emissions. They realize that large scientific uncertainties remain. But they are going to take aggressive common sense steps, introducing improvement in technologies, higher energy efficiency, less flaring of gas. They plan an internal emissions trading scheme that they think will get the results in the most economically advantageous ways.

My question is: do you think these guys know what they are talking about? This is no Mickey Mouse company — BP America is large itself, and, with a recent merger, BP in total is one of the 10 largest industrial concerns in the world.

Q2. BELC statement *[slide 19]*

I saw another thing in the newspaper that raises an even more interesting question. It was from the Pew Center — which I hadn't heard of, so I checked into what they are. The Pew Center was established this year by the Pew Charitable Trusts, one of the largest philanthropies in the U.S., which is involved in preserving the American environment. They have organized a Business Environmental Leadership Council — it includes Boeing, BP America, Enron, 3M, …

BELC statement says that every country needs to work to reduce emissions. But my question concerns the last of these points that they made: "all countries should be able to maintain or improve standards of living". Do you believe that these guys know what they are talking about — they seem to contradict what you were saying?

By the way, I'm from Iowa, and I can assure you that Maytag is a solid middle American company. So my question is: the views you expressed are drastically different than theirs — why should we accept your views about business and economics over theirs?

Q3. Wind and photovoltaic graphs. *[slide 20]*

I would like to ask some questions about the potential of clean renewable energy sources. These graphs show some examples of clean energy, renewable energy sources that do not emit greenhouse gases. These numbers are for the world. You can see that energy from wind and photovoltaics is increasing rapidly, in the world. In the U.S., they are not increasing nearly this fast — in fact, at one time the U.S. was selling almost all the devices that produced power from wind, but now we only produce 30% — probably in part because other countries take the climate issue more seriously and they are encouraging their industries.

My question concerns the potential of renewable energy. If we would encourage these sort of industries, do you think that they might provide good jobs to people, competitive with jobs in fossil fuels, like coal mining?

Q4. You have been, at least in years past, a vocal skeptic about ozone depletion, as well as global warming. My question is: now that ozone depletion has been observed, especially the Antarctic ozone hole that has recurred every year for more than a decade, do you still believe that the scientific warning about possible ozone depletion was a hoax, a concoction of models?

Affirmative Closing Argument

I want to thank Pat for participating in this discussion with me and congratulate him for being such a dynamic and capable speaker. Also, I would like to make clear that I believe that "greenhouse skeptics" such as Pat and Dick Lindzen, for example, are overall a benefit to the science of the climate change debate. Science thrives on questioning and dissent B that's the nature of science.

C1. Book review. *[slide 21]*

That does not mean that I'm entirely happy with Pat. In a recent book review, which I wrote in the *Journal of Atmospheric Chemistry*, I offered some criticisms of both extreme sides of this debate. I assert that some participants in this debate have ceased to act as scientists, but rather act as if they were lawyers hired to defend a particular perspective. New evidence has no effect on their preordained conclusions. This

is not only abhorrent to science, but it spoils the fun of it. The beauty of scientific inquiry is its logic and objectivity.

I must also say that I'm afraid this debate forum is not well suited to evaluating a scientific issue. It depends too much on rhetorical skills, rather than scientific merit. How can I deal with this? We cannot solve scientific issues here. What I can do is list the scientific questions — to try to pin down the skeptics — because the scientific community can decide these issues over the next several years. I made such a list a few weeks ago for a discussion with Dick Lindzen, but didn't get to use it. Because I have been busy at a scientific meeting all week, I couldn't change Lindzen's name, but that doesn't matter.

C2. Key differences 1&2. *[slide 22a]*

I claim that the world has warmed by 2 to 3/4 degrees Celsius in the past century, while the skeptics say that the warming is mostly an urban effect. I say that the climate sensitivity for doubled CO2 is about 3C, while they say it is much smaller.

C3. Key differences 3&4. *[slide 22b]*

I say that the water vapor feedback is positive; Lindzen says it is negative. We say that CO2 provides much of the Earth's natural greenhouse effect; Lindzen says it provides less than 2%.

C4. Key differences 5&6. *[slide 22c]*

Lindzen has said that warming will not approach natural variability in a century, while I have said it will begin to be noticeable in the 1990s, and become more obvious in the next decade. Finally, the most fundamental claim that I make is that the planet is out of energy balance with space — the whole science story flows from this issue — this is testable assertion because the only place this energy can go is into melting ice and into the ocean — hopefully we will soon have measurements of ocean heat storage.

We can make progress on all of these issues in coming years — and that is how the science debate should be decided.

C5. Affirmative closing argument. My last chart. *[slide 23]*

The scientific community has looked at the greenhouse issue for a long time, with major reports over at least two decades, from the Charney report through the IPCC reports. The vast majority of the relevant scientific community believes that, even though it is a very complicated issue with many uncertainties, the evidence is compelling enough that we should take steps to slow down the experiment while we try to understand it better.

Perhaps the most important point is that we should encourage competing technological developments. It takes decades for energy infrastructures to be developed and replaced.

I'll skip my call for research, as time is running out — but I must mention science education.

[I must also mention the need for research on the climate system. It is perplexing that, despite the emergence of climate change as a topic of global strategic importance, support for fundamental research has not increased much, especially for universities. Perhaps there is a feeling that stressing knowledge gaps is detrimental to environmental efforts, or perhaps scientists don't want to appear to be trying to "feather their nests". But good policies will depend on good understanding.]

I also want to mention science education. All students don't need to be scientists — but they should recognize the difference between astrology and astronomy — even if they enjoy using horoscopes. Students and the public need to have an accurate perception of how research works, so they can participate well in the decision making process. Climate itself is a good topic to include in general science classes, it has a lot of potential for teaching science.

One final point: if Pat's criticisms were valid, if he had evidence that we overstated global warming, why wouldn't he publish this in a refereed scientific journal? That's the ultimate success for a scientist. It would be a feather in his hat to show that our model calculations were wrong. I'm not a famous scientist, but I am a member of the National Academy of Sciences — that should be sufficient trophy for him. I think the answer is: he knows his charges can't pass scientific review. He's a practised debater. He has honed statements that sound good in public debate. But many of them are hollow scientifically.

Debate Topic

"Is There Sufficient Scientific Evidence That Proves We Should Substantially Limit Greenhouse Gas Emissions Because of Climate Change?"

My Opinion

1. Climate is Changing (Global Warming)

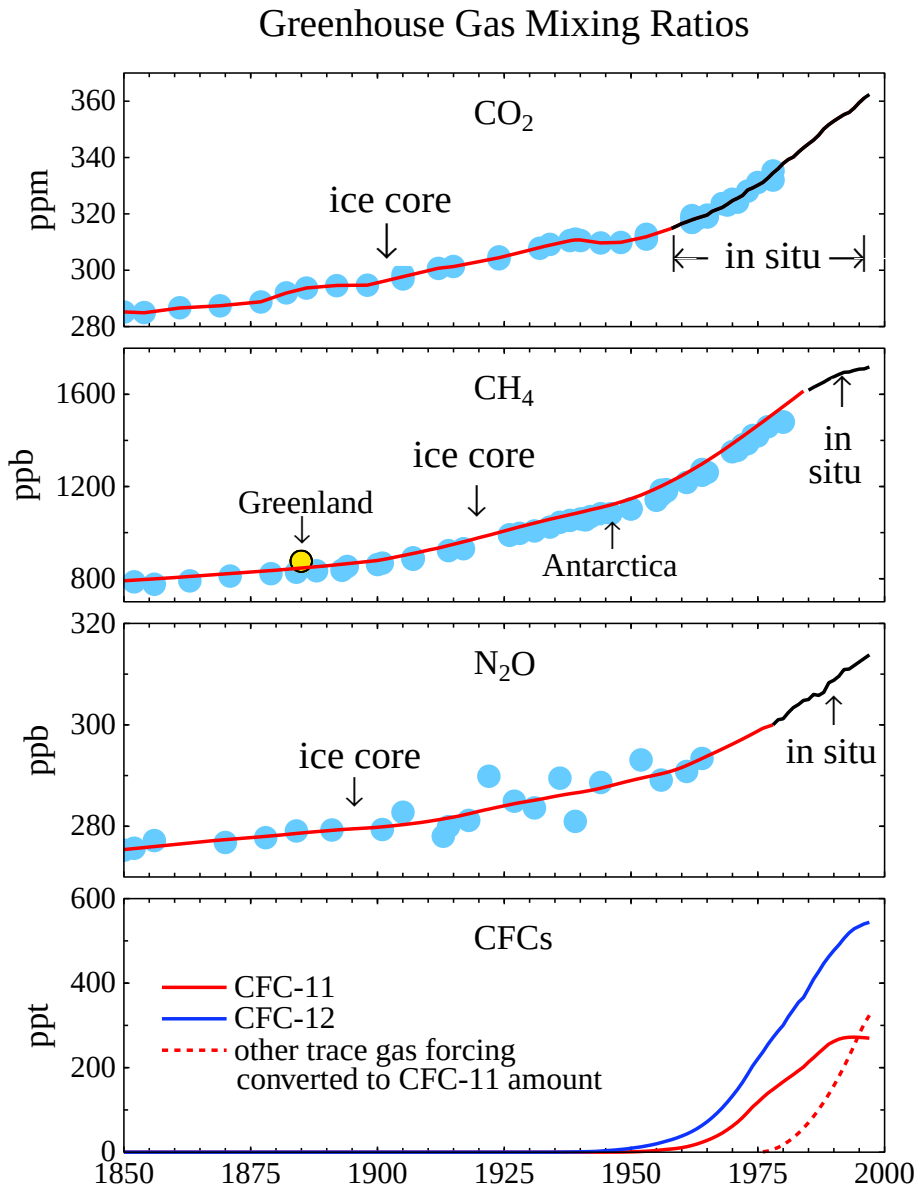
2. Human (Greenhouse Gas) Role is Probable

3. Global Warming Increases Hydrologic Extremes (droughts/fires and heavy rain/floods)

4. With Large Climate Change, Detrimental Effects Probably Exceed Beneficial Ones

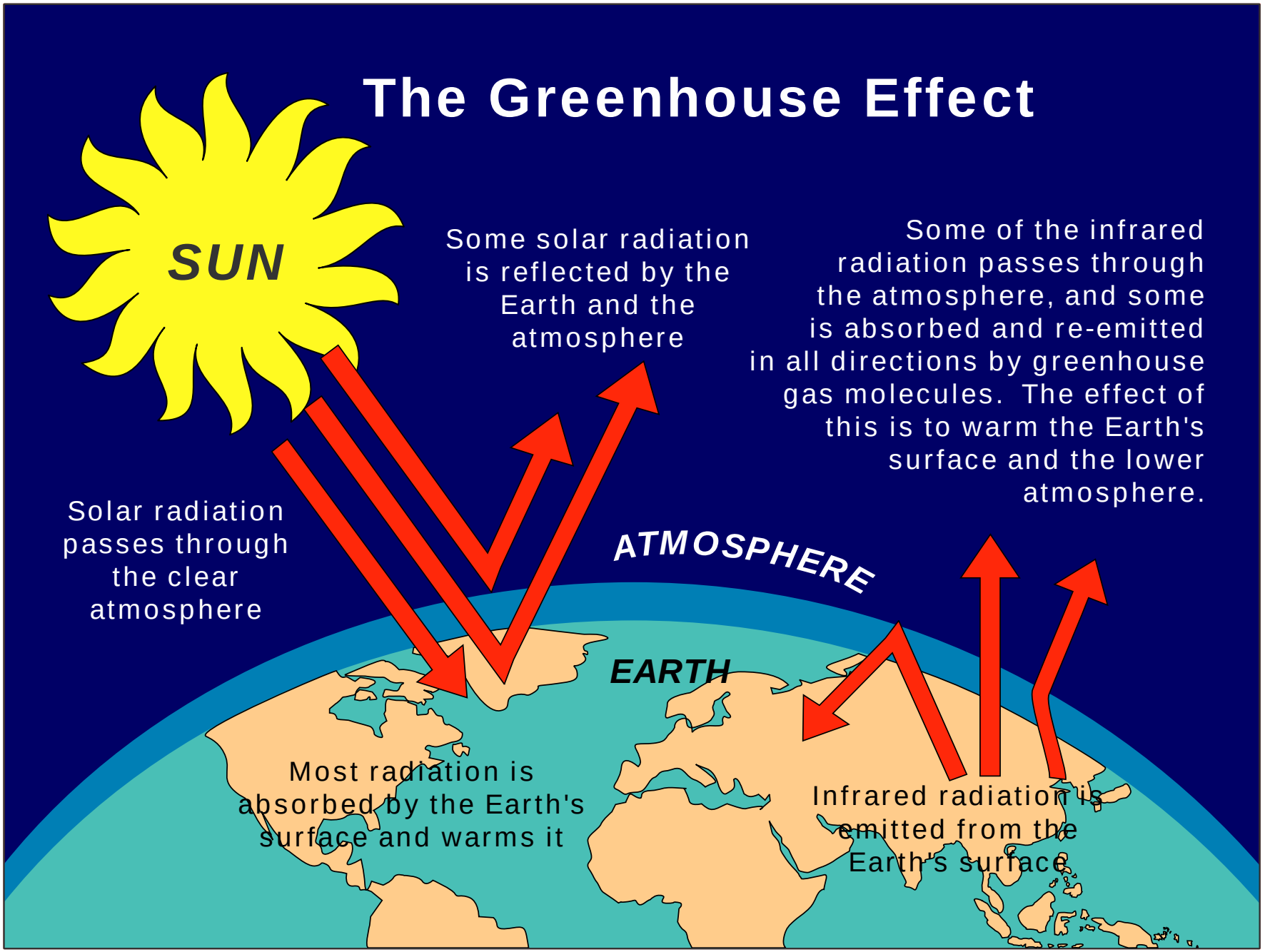
5. Common Sense Steps to Limit Climate Change Are Warranted

SLIDE 3



Principal anthropogenic greenhouses in the industrial era. (Proc. Natl. Acad. Sci. 22, 12753-12758.)

SLIDE 4


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it
Infrared radiation is emitted from the Earth's surface

SLIDE 5

"Charney Report"*

Estimate of equilibrium global climate sensitivity:

3±1.5C for doubled CO_2

Bottom line of report:

"To summarize, we have tried but have been unable to find any overlooked or underestimated physical effects that could reduce the currently estimated global warming due to a doubling of atmospheric CO_2 to negligible proportions…"

*Carbon Dioxide and Climate: A Scientific Assessment, 1979: J. Charney (Ed.), National Academy of Sciences, Washington, D.C., 22pp. Ad Hoc Study Group on Carbon Dioxide and Climate: Jule G. Charney (chairman), Akio Arakawa, D. James Baker, Bert Bolin, Robert E. Dickinson, Richard M. Goody, Cecil E. Leith, Henry M. Stommel, Carl I. Wunsch.

SLIDE 6

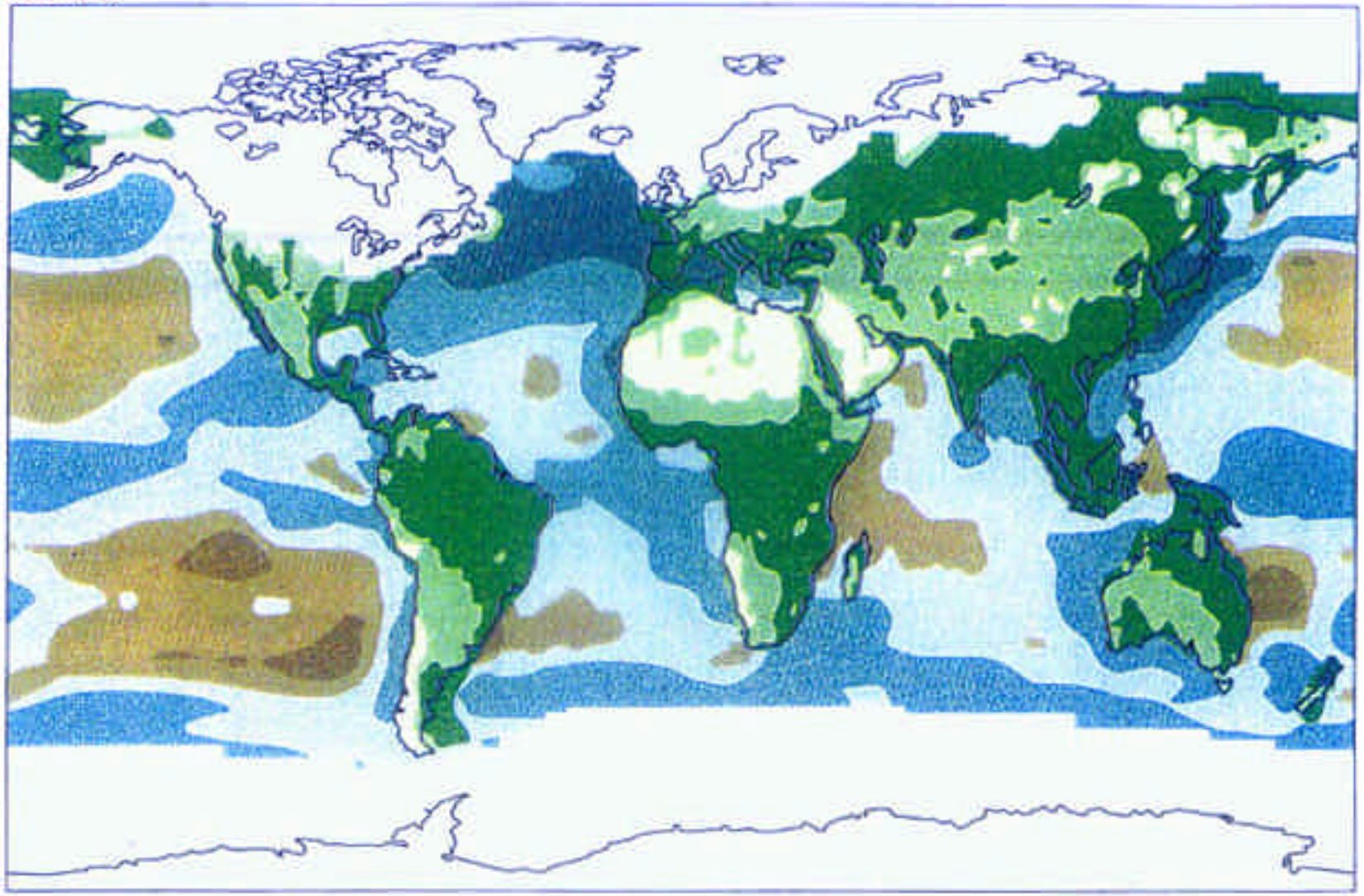


Figure 5.
Surface conditions in August during the last major ice age, ~20 000 years ago.[9]

SLIDE 7

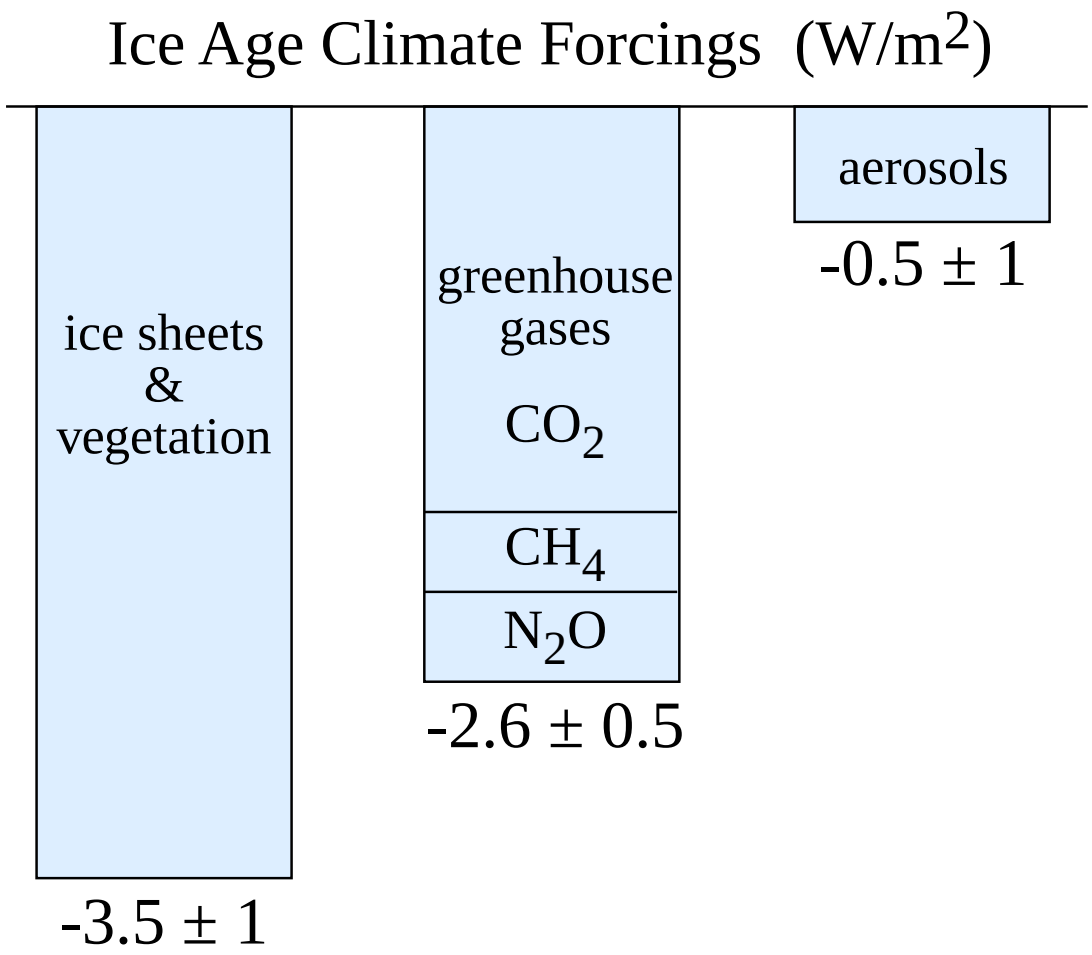
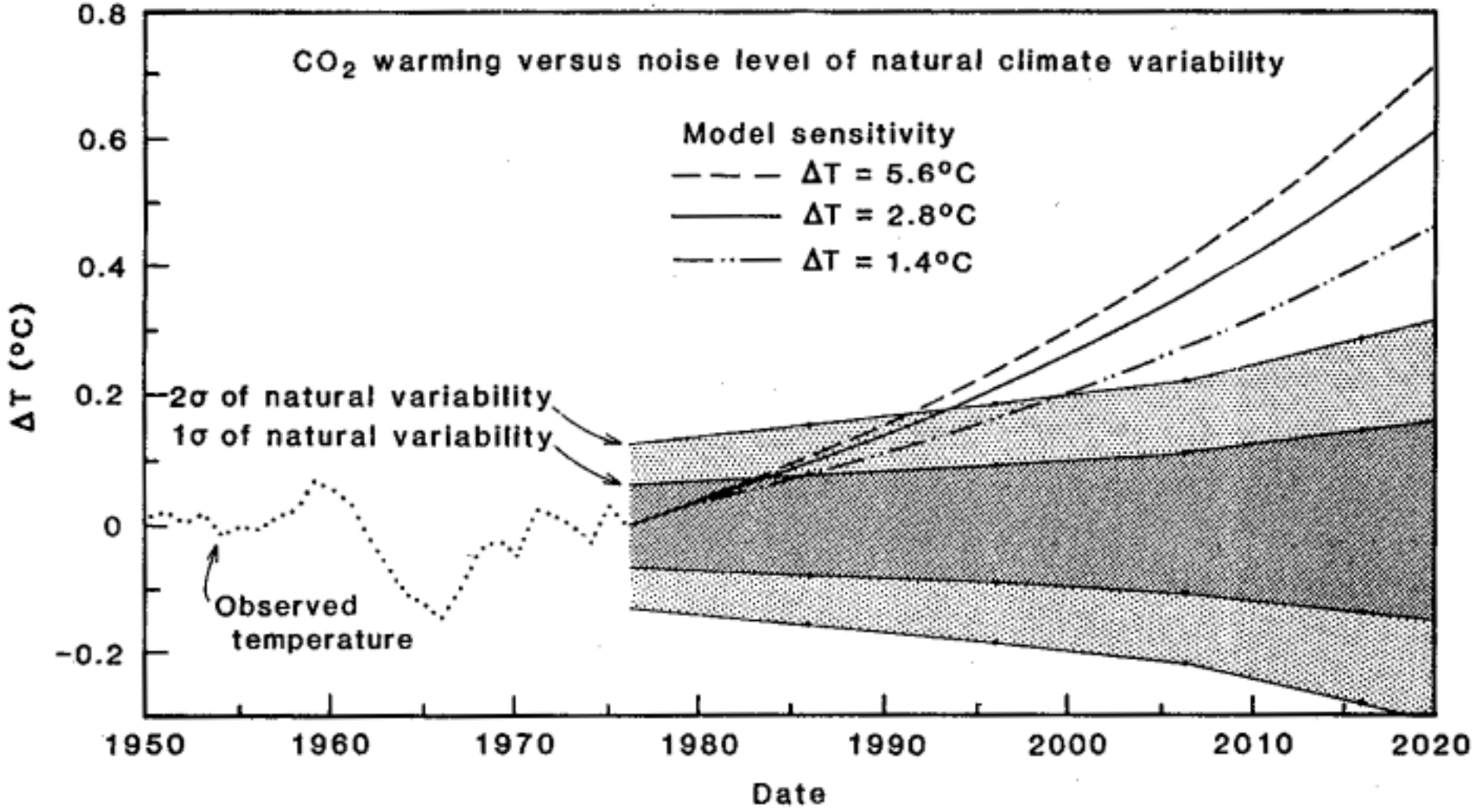


Fig 2. Global radiative forcings during the last ice age relative to the current interglacial period. The total forcing is -6.6 ± 1.5 W/m^2. Thus, the 5°C cooling of the ice age implies a climate sensitivity of 0.75°C per 1 W/m^2 forcing.

Hansen, J. et al., The missing climate forcing, Phil. Trans. R. Soc. London. B, 352, 231-240, 1997.

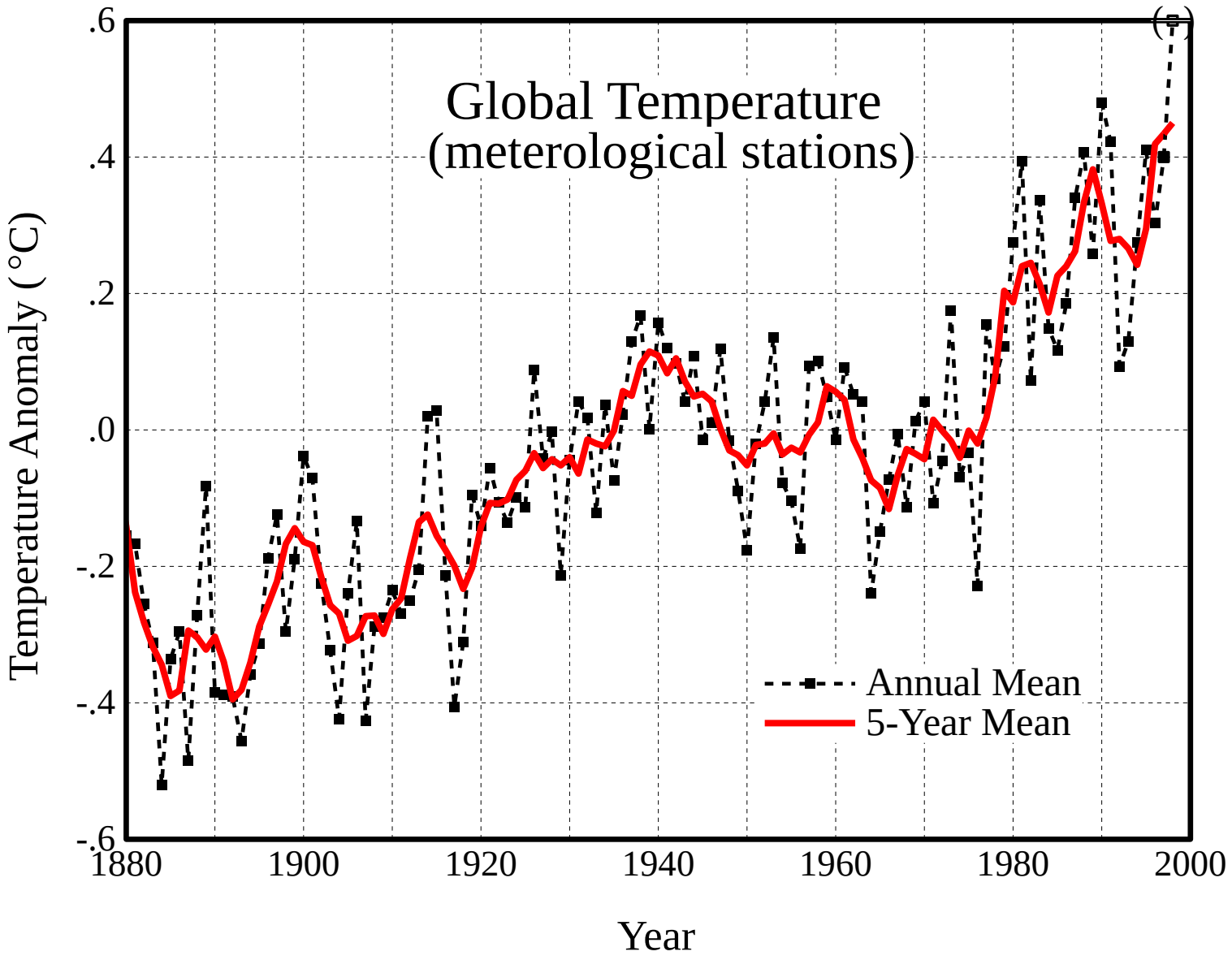
SLIDE 8



Comparison of projected CO_2 warming to standard deviation (σ) of observed global temperature and to 2σ. The standard deviation was computed from observed 5-year mean global temperatures. Carbon dioxide change is from slow-growth scenario. The effect of other trace gases and aerosols (which at least partially cancel) are not included.*

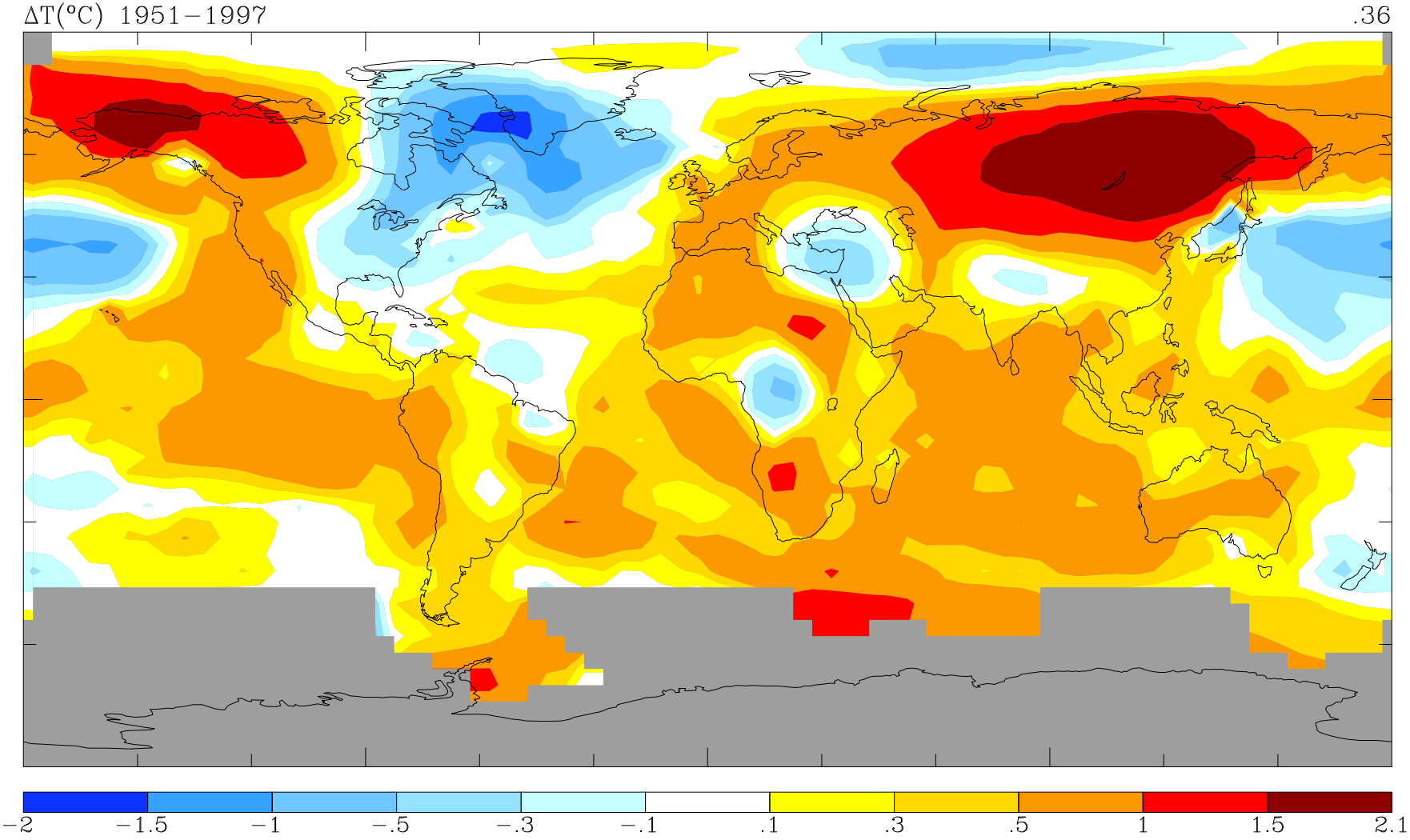
* Hansen, J., D. Johnson, A. Lacis, S. Lebedeff, P. Lee, D. Rind, and G. Russell 1981. Climate impacts of increasing atmospheric CO_2. *Science* **213**, 957-966.

SLIDE 9



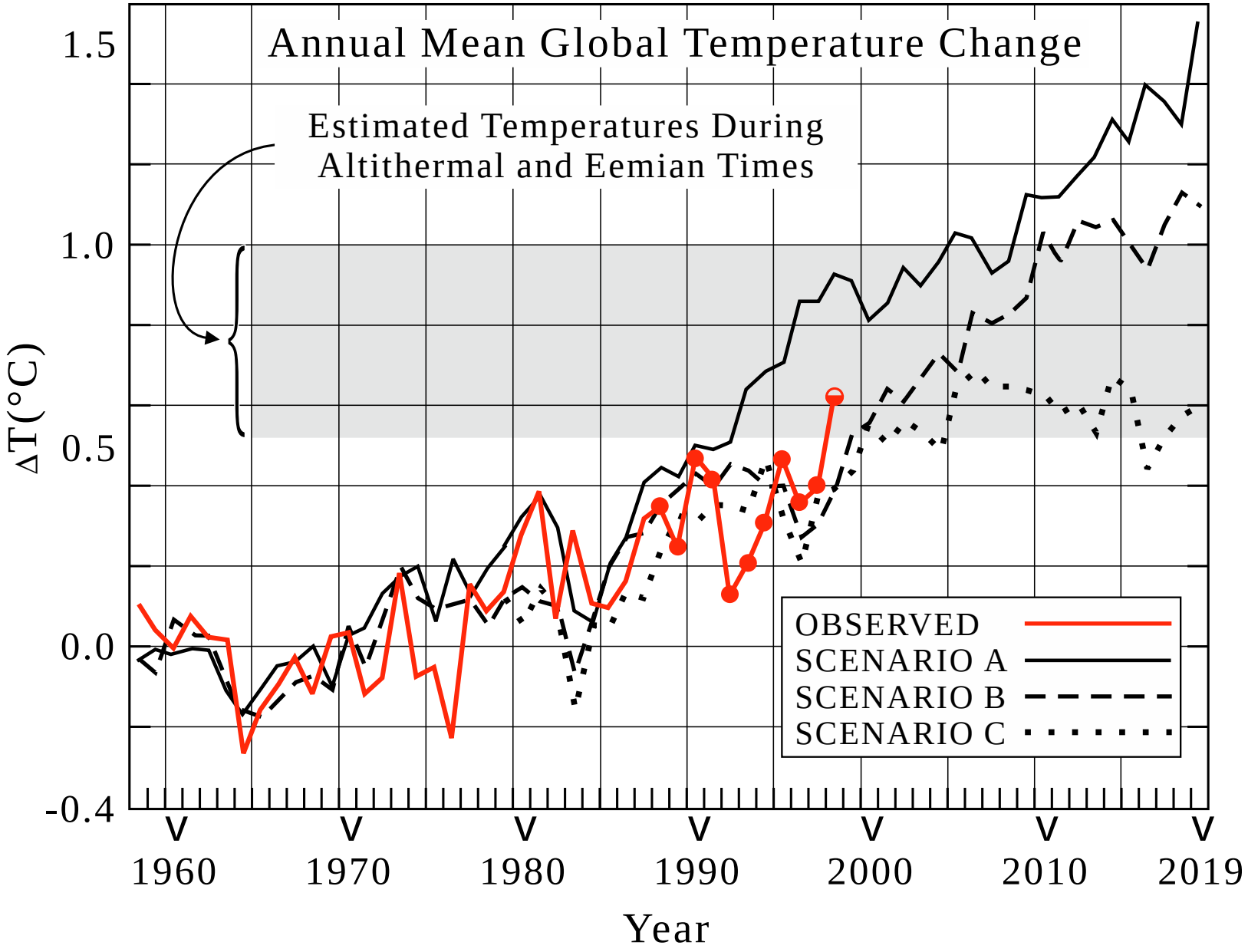
Global surface air temperature change estimated from measurements at meteorological stations (*Geophys. Res. Lett.* **23**, 1665-1669, 1996).

SLIDE 10



Surface temperature change for 1951-1997 based on local linear trends. (Proc. Natl. Acad. Sci. 95, 4113-4120, 1998).

Slide 11



Climate model calculations carried out in 1987 (Hansen, J., I. Fung, A. Lacis, D. Rind, S. Lebedeff, R. Ruedy, G. Russell, and P. Stone. *J. Geophys. Res.* **93**, 9341-9364, 1988).

Senate Testimony, 1988 & 1989

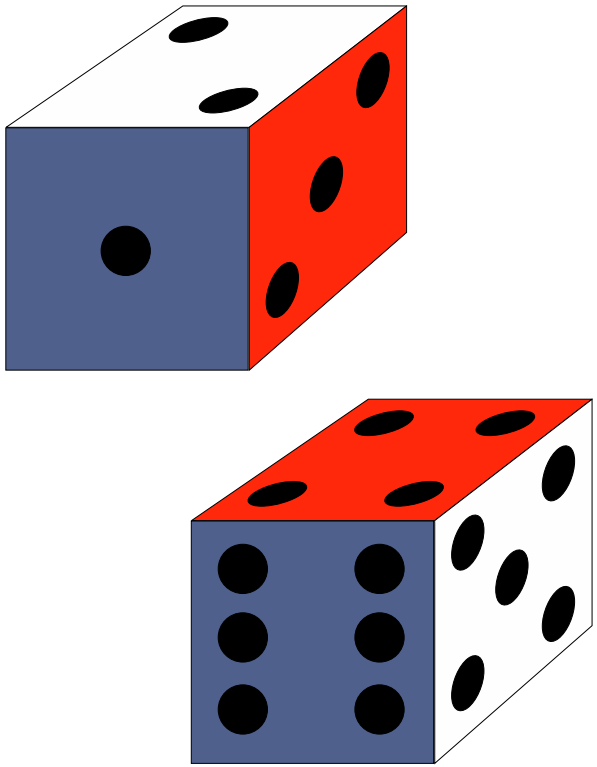
1. Global warming underway (99% confidence)

2. Probably due to greenhouse effect (high confidence)

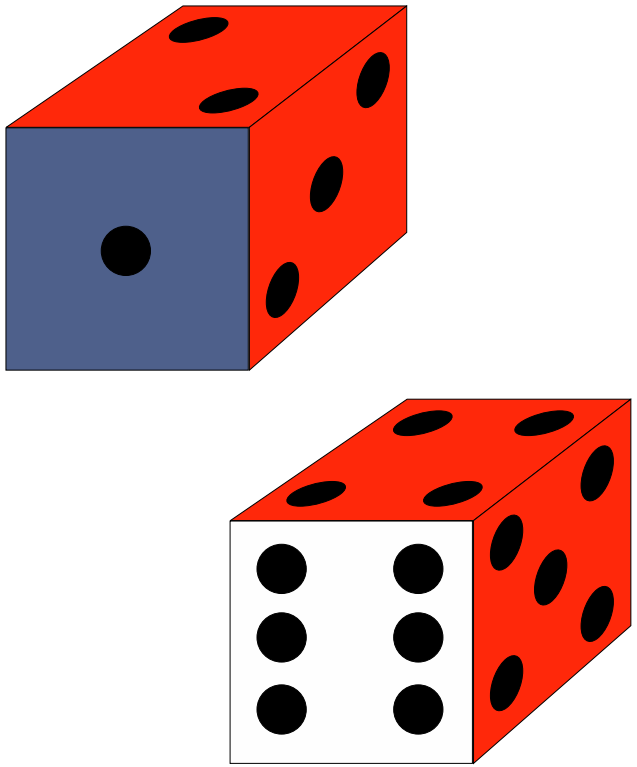
3. Model predicts increasing frequency of extremes:

    a. High temperatures, droughts, fires

    b. Heavy rain, floods

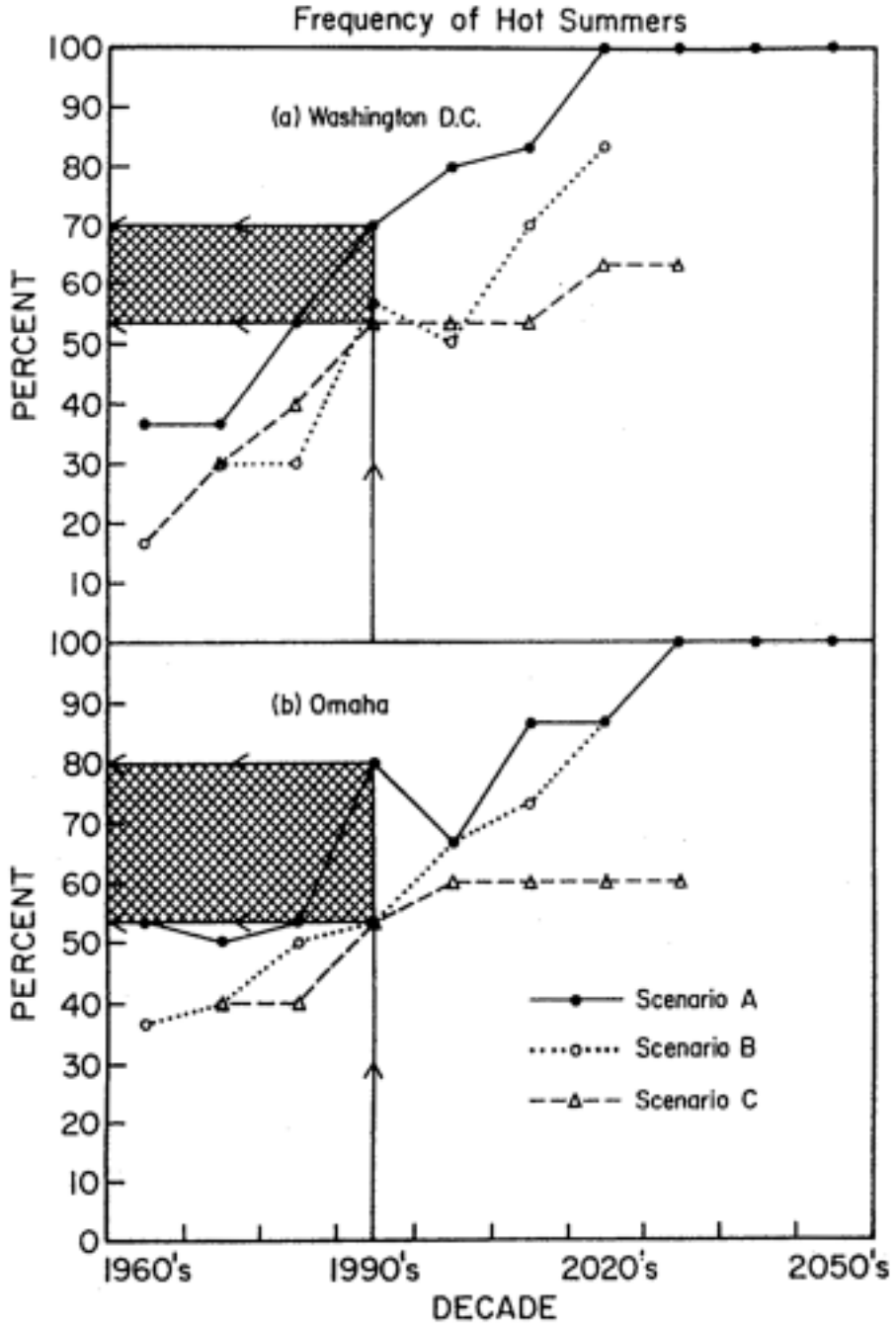


1951-1980
Climatology



1990's
Predicted

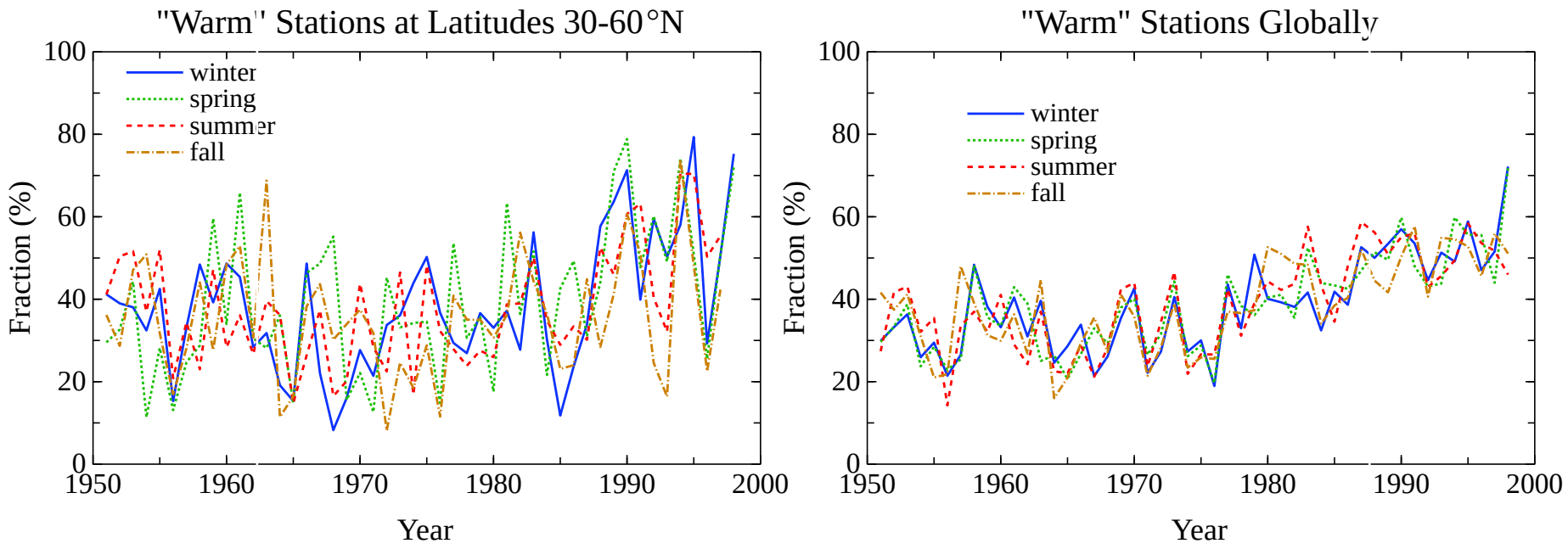
SLIDE 14



Calculated probability of the summer being "hot", shown at two locations for greenhouse gas scenarios A, B, C. A "hot" summer is one in which the mean temperature exceeds a value chosen such that one third of the summers were "hot" in 1950-1979 observations.

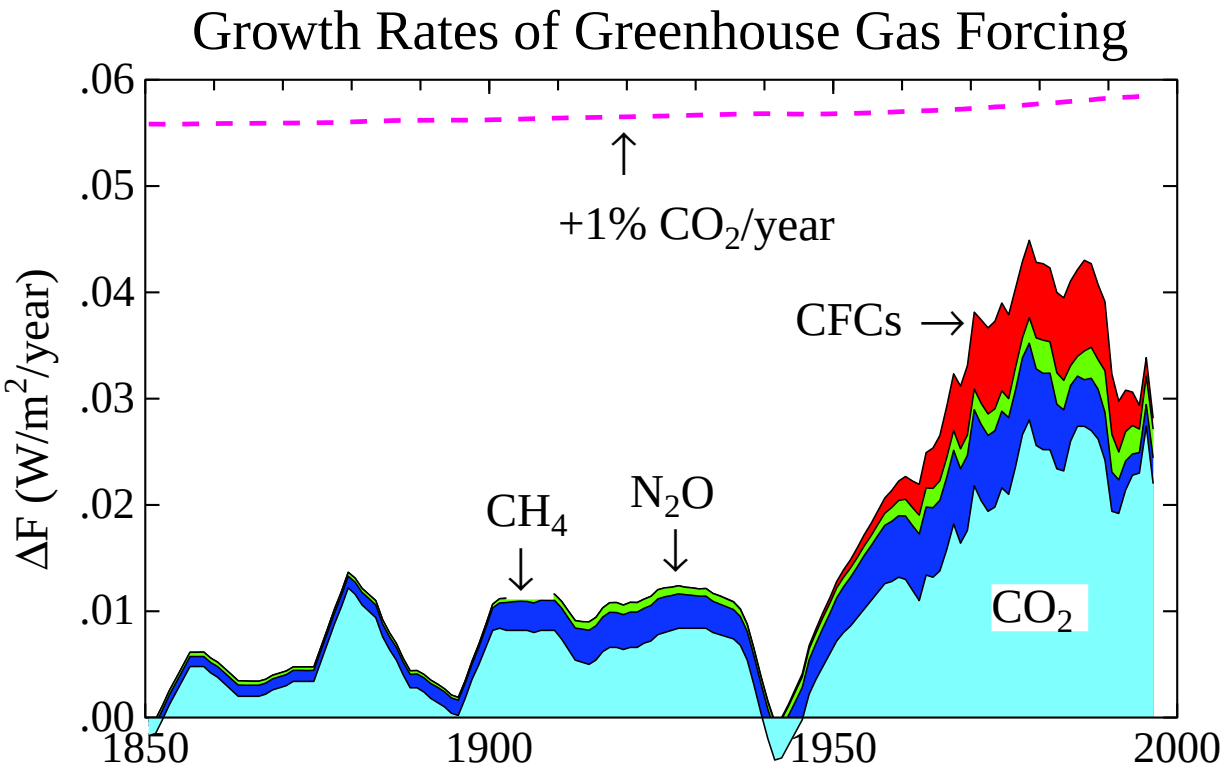
From "Global climate change as forecast by GISS 3-Dimensional model" *J. Geophys. Res.* **93**, 9341-9364, 1988.

SLIDE 15



Hansen, J., Public understanding of global climate change, in Carl Sagan's Universe, Cambridge Univ. Press, 1997, pp. 247-253.

SLIDE 16



Growth rate of greenhouse climate forcing based on gas histories. Dashed line is forcing due to 1% CO_2 increase.

Hansen, J., M. Sato, A. Lacis, R. Ruedy, I. Tegen, and E. Matthews. 1998. Perspective: Climate forcings in the industrial era. Proc. Natl. Acad. Sci. 22, 12753-12758.

Summary Statement

1. Empirical evidence: climate sensitivity to forcings

2. Greenhouse gases increasing rapidly

3. Global warming observed & consistent with expectations

4. Large uncertainties regarding future climate change

5. Impacts of climate change uncertain, but we are adapted to current climate

6. Common sense strategy: slow down the planetary experiment and adjust strategy with experience

7. Many opportunities to slow the global experiment exist (e.g., energy efficiency, renewable energy technologies)

British Petroleum (BP) Statement
(John Browne, Chief Executive)

- BP announced a “firm target” to cut emissions by 10% of 1990 levels by 2010.
- “…science of climate change is not proven… …but there is mounting evidence that the concentration of carbon dioxide in the atmosphere is rising and the temperature of the earth’s surface is increasing.”
- Expected savings from: technology improvements, energy efficiency, less flaring,…
- BP has initiated an internal program enabling units within the company to trade emissions rights.

Pew Center on Global Climate Change
Business Environmental Leadership Council

Air Products and Chemicals, Inc. *American Electric Power * Baxter International Inc. * Boeing Company * BP America *CH2M HILL * Dupont * Enron Corp. * Holnam Inc. * Intercontinental Energy Corporation * Lockheed Martin * Maytag Corporation * The Sun Company * 3M * Toyota * United Technologies * U.S. Generating Company * Whirlpool

→ "…every country.. ..needs to work to the best of their ability in addressing the climate change issue."

→ "…countries that must lead the way.. ..those that emit the most, enjoy the highest standard of living.. ..or have the most opportunities to reduce their emissions."

→ All countries should be able to maintain or improve standards of living as they work to address climate change

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FIGURE 5

World Wind Energy Generating Capacity, 1980–97

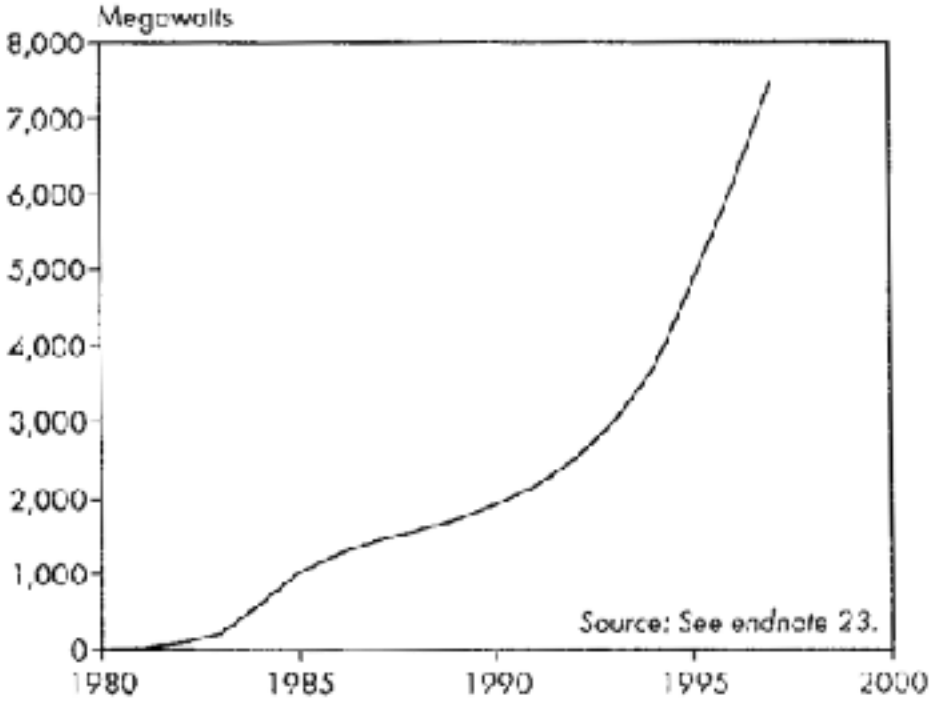
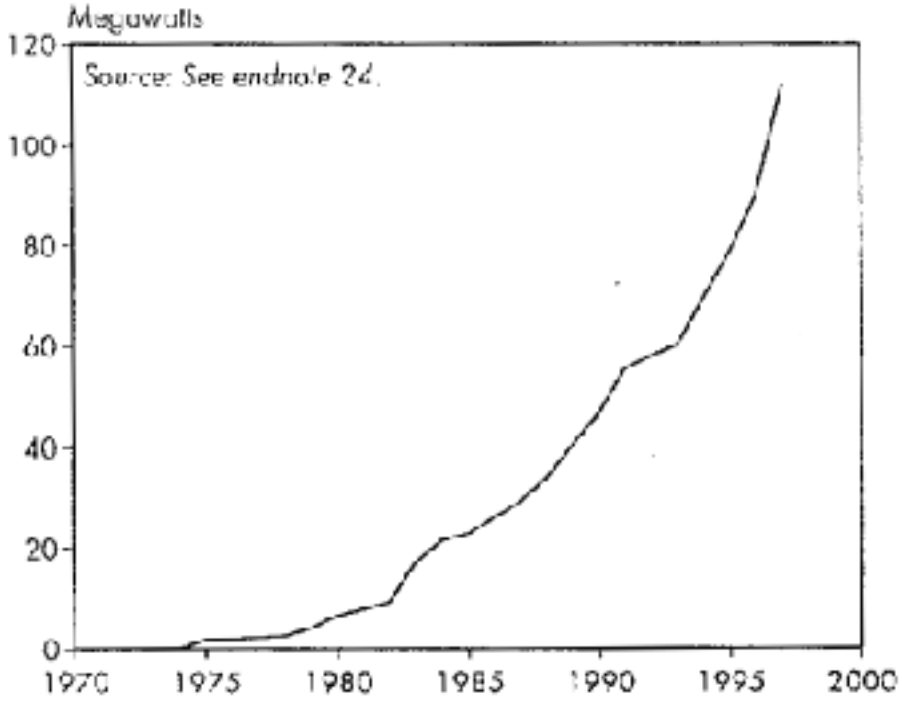


FIGURE 6

World Photovoltaic Shipments, 1971–97



24. Solar power data, including Figure 6, from Molly O'Meara, "Solar Cell Shipments Keep Rising," in Brown et al., op cit., note 23; Flavin and Lenssen, op. cit. note 5; 1997 figure is preliminary Worldwatch estimate.

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Role of Scientists in Global Warming Debate

Houghton quotes Albert Einstein as saying 'The most incomprehensive thing about the universe is that it is comprehensible' and Houghton connects this with a responsibility of scientists to be stewards of the Earth. We can all agree on the need for environmental responsibility, and even relish the prospect that our research might contribute to environmental well being. But I believe that Einstein's statement is more a marveling at the fact that it is possible, at least to a degree, to figure out how the world works. This marvel, and the implied fun and excitement in research, drives scientists in their pursuit of understanding. The essence and the beauty of iterative scientific inquiry is its logic and objectivity, and its success depends upon open-minded unbiased interpretation of each new piece of data.

Injection of environmental and political perspectives in midstream of the science discussion cannot help the process of inquiry. I believe that persons with relevant scientific expertise should concentrate, with pride, on cool objective analysis, providing information to the public and decision-makers when it is found, but leaving the moral implications for later common consideration, or at most for summary inferential discussion. I am not implying bias on the part of any particular scientist. But the global warming debate has plentiful examples to illustrate my thesis, especially, at least on a per capita basis, among the most vociferous greenhouse 'skeptics', i.e., those who challenge the reality or interpretation of global warming. Many of the participants in this debate have ceased to act as scientists as defined above, but rather act as if they were lawyers hired to defend a particular perspective. New evidence has no effect on their preordained conclusions. This is abhorrent to science and spoils the fun of it.*

* Hansen, J., 1998: *J. Atmos. Chem.*, **30**, 409-412 [Book review of Sir John Houghton's Global Warming: The Complete Briefing, Cambridge University Press].

Key Differences with Skeptics

1. Observed global warming: real or measurement problem?

Hansen: global warming is 0.5-0.75°C in past century, ~0.3C in past 25 years.

Lindzen: since about 1850 "…more likely … 0.1±0.3°C" (MIT Tech Talk, 34, #7, 1989).

2. Climate sensitivity (equilibrium response to $2xCO_2$)

Lindzen: ≤ 1°C

Hansen: 3±1°C

Comments: paleoclimate data, improved climate models, and process studies may narrow uncertainties; observed climate change on decadal time scales will provide constraint if climate forcings are measured; implicit information on climate sensitivity can be extracted from observed changes in ocean heat storage.

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3. Water vapor feedback

Lindzen: negative, upper tropospheric water vapor decreases with global warming
Hansen: positive, upper and lower tropospheric water vapor increase w global warming

References: (these include references by Lindzen stating that, in response to global warming, water vapor will decrease at altitudes above 2-3 km)

Comment: accurate observations of interannual changes (several years) and long-term changes (1-2 decades) of upper tropospheric water vapor could provide defining data

4. CO_2 contribution to the ~33°C natural greenhouse effect

Lindzen: "Even if all other greenhouse gases (such as carbon dioxide and methane) were to disappear, we would still be left with over 98 percent of the current greenhouse effect. Cato Review, Spring issue, 87-98, 1992; "If all CO_2 were removed from the atmosphere, water vapor and clouds would still provide almost all of the present greenhouse effect." Res. Explor. **9**, 191-200, 1993.
Lacis and Hansen: removing CO_2, with water vapor kept fixed, would cool the Earth 5-10°C; removing CO_2 and trace gases with water vapor allowed to respond would remove most of the natural greenhouse effect.

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5. When will global warming and climate change be obvious?

Lindzen: I personally feel that the likelihood over the next century of greenhouse warming reaching magnitudes comparable to natural variability remains small.

Hansen: “With the climatological probability of a hot summer represented by two faces (say painted red) of a six-faced die, judging from our model by the 1990s three or four of the six die faces will be red. It seems to us that this is a sufficient ‘loading’ of the dice that it will be noticeable to the man in the street.” J. Geophys. Res. 93, 9341-9364, 1988.

6. Planetary disequilibrium

Hansen: Earth is out of radiative equilibrium with space by at least approximately 0.5 W/m2 (absorbing more energy than it emits)

Comments: This is the most fundamental measure of the state of the greenhouse effect. Because the disequilibrium is a product of the long response time of the climate system, which in turn is a strong function of climate sensitivity, confirmation of the disequilibrium provides information on climate sensitivity and an indication of how much additional global warming is “in the pipeline” due to gases already added to the atmosphere.

This disequilibrium could be measured as the sum of the rate of heat storage in the ocean plus the net energy going into the melting of ice. Existing technology, including very precise measurements of ocean and ice sheet topography, could provide this information.

Affirmative Closing Argument

1. There is strong basis for concern about human-made climate effects, but there are also many scientific uncertainties

2. Evidence sufficiently compelling to warrant slowing down the "planetary experiment" by reducing greenhouse gas emissions

3. Common sense strategic approach – invest in:

   → Alternative Energies & Energy Efficiency

   → Research Reducing Uncertainties

   → Public Science Education/How Research Works

   → Adjust Policies as We Learn